Research on Multiprocessing Techniques for Multifunctional Satellites

Contract NAS 12-660

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RESEARCH ON MULTIPROCESSING TECHNIQUES FOR MULTIFUNCTIONAL SATELLITES

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RESEARCH ON MULTIPROCESSING TECHNIQUES

FOR MULTIFUNCTIONAL SATELLITES

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FOREWORD

This Final Report describes the results of a study conducted under NASA contract NAS 12-660, "Research on Multiprocessing Techniques for Multifunctional Satellites." It was performed by International Business Machines Corporation, Federal Systems Division, Communications and Engineering Sciences Center, in Gaithersburg, Maryland. The work was administered under the direction of the National Aeronautics and Space Administration, Electronics Research Center, Computer Research Laboratory, Cambridge, Massachusetts. Mr. G. Y. Wang and Mr. J. Roy provided the NASA Technical Direction of this study.

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CONTENTS

Abbreviations

ACS	-	Attitude Control Subsystem
A/D	-	Analog-digital Converter
APT	-	Automatic Picture Transmission
C/O	-	Checkout
D/A	-	Digital-analog Converter
ESMR	-	Electrically Scanned Microwave Radiometer
GROW	-	Global Radar for Ocean Waves and Winds
HDRSS	-	High Data Rate Subsystem
HRIR	-	High Resolution Infrared Radiometer
HRMR	-	High Resolution Surface Composition Mapping
I/O	-	Input/output
ITPR	-	Infrared Temperature Profile Radiometer
MICSPEC	-	Microwave Spectrometer
MP	-	Multiprocessor
MUX	-	Multiplex Operation
OCS	-	On-board Checkout System
PICOM	-	Positive Ion Composition
PROBE	-	Electrostatic Probe
S/C	-	Spacecraft
SCRWV2	-	Selective Chopper Radiometer
T/M	-	Telemetry
VIP	-	Versatile Information Processor
VPOC	-	Vertical Profile of Ozone Concentration

Illustrations

Illustrations - continued

TABLES

TABLES - continued

SECTION 1

INTRODUCTION

This report documents the accomplishments of Phase II of contract NAS 12-660 "Research on Multiprocessing Techniques for Multifunctional Satellites." The basic objective of this contract is to examine the use of a multiprocessor computer configuration for data management, data processing, and spacecraft operations for Application Satellites. Toward that end the Nimbus E mission has been selected using the Nimbus D spacecraft as the platform. The experiments selected for this study and their desired outputs are:

1. Electrically Scanned Microwave Radiometer (ESMR) — Imagery
2. High Resolution Infrared Radiometer (HRIR) — Imagery
3. High Resolution Surface Composition Mapping (HRMR) — Imagery of Earth's Surface
4. Infrared Temperature Profile Radiometer (ITPR) — Profile of Temperature and Water Vapor
5. Selective Chopper Radiometer (SCRWV2) — Profile of Temperature and Water Vapor
6. Microwave Spectrometer (MICSPEC) — Temperature and Water Vapor Profiles
7. Positive Ion Composition (PICOM) — Global Ion Composition Mapping

8. Global Radar for Ocean Waves and Wind (GROW) — Imagery of Wave Height and Winds

9. Vertical Profile of Ozone Concentration (VPOC) — Profile of Ozone Concentration

10. Electrostatic Probe (PROBE) — Electron Temperature Measurement (point)

11. Realtime Data Relay via ATS-F (DRS) — Data Transmission via a Stationary Satellite

The concept of using a multiprocessor for Application Satellites offers many advantages. These include:

- Increased realiability
- Shorter mission development time
- Cost savings
- Efficient experiment management via experiment "cross talk"
- Real time processed data

The basic idea of a multiprocessor is a computer organization in which a particular function does not depend on a particular piece of hardware. As failures occur, the total capability of the computing system is decreased but all functions will still be accomplished according to their priority. In this manner the total system reliability may be increased.

The shorter mission development time and cost savings are achieved by eliminating the requirement for the experimenters to fabricate much of the hard wired equipment for their experiment. The sensor would be connected directly to the processor which would provide the control, calibration, checkout, and data handling functions. The present mission development time may take six to eight years from experiment concept until flight of which three to four are for equipment fabrication. With a processor already built, the experiment hardware development consisting of sensor and supporting hardware is replaced by sensor and software support. This should reduce experiment development time by one to two years, and by reducing the amount of one time hardware development experiment costs should be reduced proportionately.

The use of a multiprocessor concept also provides an easy method to change the mission should that be desired. Should RFI, antenna, sensor development or other problems require a change in the experiment package to be flown, an off the shelf sensor or backup experiment sensor can be substituted and the appropriate software loaded into the computer. This same capability permits the spacecraft constants such as control loop gain, telemetry formatting, data compression technique, experiment control, etc., to be changed throughout mission development and even after launch.

Efficient experiment management is achieved by being able to use the output of one experiment to control another sensor. For example, if one experiment requires cloud free conditions, the output from a cloud sensing sensor could be used to determine if useful data can be obtained from the first experiment. In a similar vein one of the experiment sensors could be substituted for a horizon or sun sensor in the attitude control system should a failure occur. All that is required is a means for getting processed sensor data to the attitude control system and the multiprocessor would provide that means.

The ability to make information available in real time has been proven to be extremely valuable in the field of meteorology. Cloud cover images relayed in real time have been effectively used by local meteorologists. On board processing of such data permits enhancement, calibration and gridding to be included in the data and will permit the real time availability of temperature and water vapor profiles which are also of prime importance to forecasters.

The Phase I report considered the experiments and spacecraft operations that would be implemented by the processor. The general mission configuration is as shown in Figure 1-1. In general, all data handling and processing functions will be accomplished in the computer. It has been assumed that the standard Nimbus D spacecraft hardware

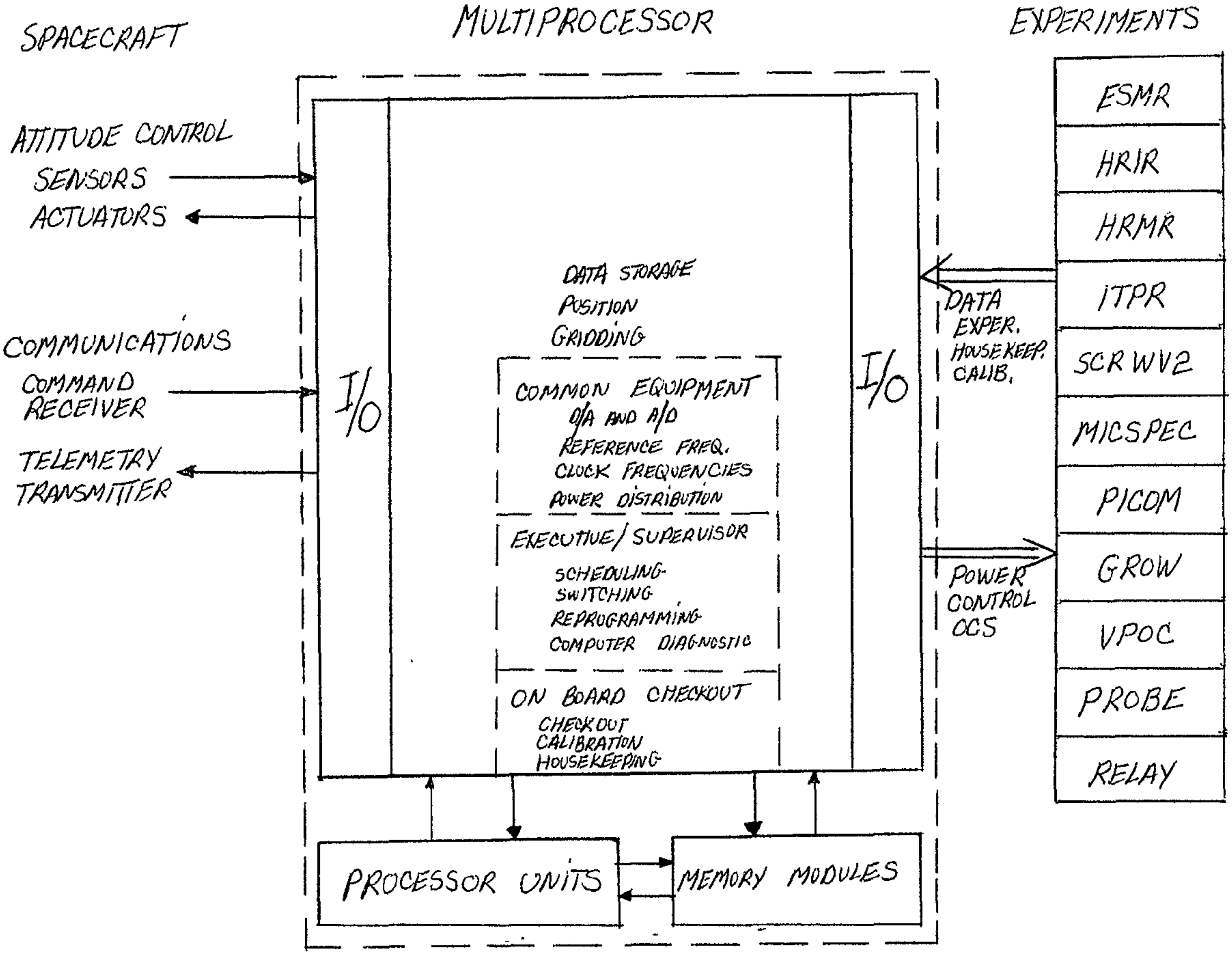

FIGURE 1-1 MISSION CONFIGURATION

such as the attitude sensors, reactive jets and momentum wheels, tape recorders, transmitters, etc. will remain. The general multiprocessor configuration illustrated in Figure 1-2 was identified during contract NAS 12-507, "Multiprocessing Techniques for Unmanned Multifunctional Satellites."

This Phase II report details the functions that the processor must perform. The experiment control, data handling and spacecraft operations are described, flow charts developed, instructions and data storage requirements judged, and operations/sec. estimated. In addition to controlling the spacecraft and experiment operations, the processor will perform specific data processing functions. These functions are:

1. Processing of imagery data (ESMR, MRIR, MRMR, PICOM, GROW) including:
   a. Sun angle correction
   b. In flight calibration
   c. Laboratory curve correction
   d. Gridding
2. Processing of temperature and humidity profiling data (ITPR, SCRWV2, MICSPEC, VPOC) including:
   a. Sun angle correction
   b. In flight calibration

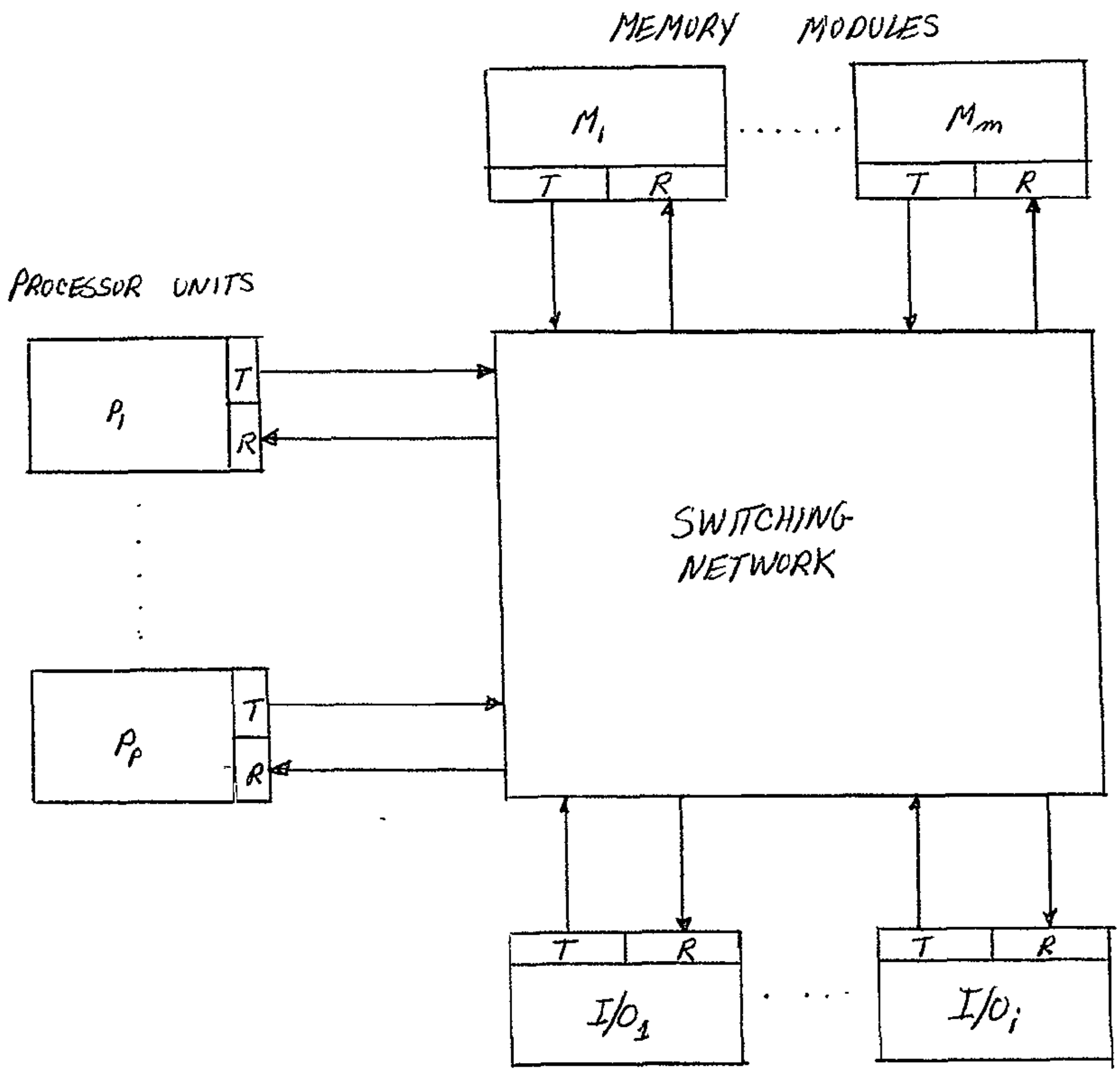

FIGURE 1-2 MULTIPROCESSOR SYSTEM

c. Laboratory curve correction

d. Radiative transfer matrix inversion to obtain profile

e. Gridding

It is in this area where on board processing has its greatest potential. The striking success of the Automatic Picture Transmission (APT) concept flown on TIROS VIII, Nimbus I, ESSA-2, Nimbus II, and others has demonstrated the great value of APT data to local meteorological stations. A real time system capable of also producing temperature and humidity profiles as well as calibrated, gridded imagery would be of even greater assistance to forecasters, ships at sea, and many other users of weather information.

The functions and requirements of the executive/supervisor of the processor are also examined as well as an on-board checkout system. These two operations control the entire system. The assignments of processing and memory modules to certain tasks, equipment evaluation and equipment scheduling control the operation of the multiprocessor.

SECTION 2

EXPERIMENTS

This section deals with the given set of experiments, their Characteristics, Processing Requirements, and possible Common Interface. The given set of experiments are those which are candidates for the Nimbus E Spacecraft.

2.1 CHARACTERISTICS

Keeping in mind that the end product of this study is a design of a multiprocessor to be used on a operating system, the following assumptions were made:

- Sensors will incorporate some method of inflight calibration which will be an integral part of its observation cycle.
- Sensors may have spare circuits, components, or modules which can be switched in or out as a failure is detected.
- The equipment will not be in an experimental status, i. e., the general processing requirements for each sensor will be known.
- All scanning or pointing will be controlled by the multiprocessor.

The following assumptions were not included but should be considered for future operating systems:

- The sensors will have a much higher resolution than those considered in the given set of experiments.
- Due to higher resolution the data rates will be greater.
- Radiometers will probably be of the vidicon tube type.
- One sensor package will perform the combined tasks of several of the experiments in the given set.
- Radiometers will probably have data rates of 35KHz per channel.

Table 2. 1-1 is a summary of the more important characteristics of the experiments used in this study. Several interesting observations are brought to light as the table is studied, not the least of which is the fact that there is considerable overlap in the sensing of certain regions of the spectrum. The table also lists the types of observations, approximate data rates, dimensions of the scan, and the approximate sampling rates.

Table 2. 1-2 list the types of processing, which could be performed on the data depending upon the type of output desired.

Following these tables is a list of the experiments with their detailed characteristics grouped under the following headings: Input (to the

experiment), Output (from the experiment), Stabilization and Control (requirements of the experiment), and Processing (requirements peculiar to the experiment).

Experiment Acronym	Number of Channels	Spectrum of Channels	Usage Time/Day	Measurement Range	Dimensions of Scan	Samples per Scan/ Sensor	Read Time per Scan	Peak Sampling Rate/ Sec.	Peak Data Rate (BPS)	Average Data Rate per Scan (BPS)
ESMR Image	1	1.55 cm (19.35 GHz)	12 hrs.	50 to 330°K	1.6° x 100°	63	1.4 sec	45	360	101
HRIR Image	1 1	0.45 to 0.75μ 10.0 to 12.0μ	24 hrs.		0.3° x 120°	400	0.3 sec	2.7K	21.6K	6,400
HRMR Image	1 1	8.4 to to 9.4μ 10.2 to 11.4μ	2.4 hrs		0.03° x 60°	2000	0.017	235.3K	1.88M	320,000
ITPR Profile	1 1 4	6.7μ (Water Vapor Band) 11.1μ 15μ (CO_2 Band)	24 hrs.		2.5° x 72.5°	29	6.0	29	232	232
SCRWV2 Profile	4 7 1 1	9 to 18μ (Temperature and Water vapor) 15μ (CO_2 Band) 45μ 133μ (Cirrus Clouds)	9 hrs.	0 to 0.35 millibars 200 to 250°K	0.6°	1	1	13	104	104
MICSPEC Profile	1 1 1 1 1	1.35 cm (22.2 GHz) 0.95 cm (31.4 GHz) 0.55 cm (53.65 GHz) 0.49 cm (60.82 GHz) 0.47 cm (64.47 GHz)	24 hrs.	0 to 400°K	9°	1	5	1	8	8

SUMMARY OF THE EXPERIMENT CHARACTERISTICS

TABLE 2.1-1

Experiment Acronym	Number of Channels	Spectrum of Channels	Usage Time/Day	Measurement Range	Dimensions of Scan	Samples per Scan/ Sensor	Read Time per Scan	Peak Sampling Rate/ Sec	Peak Data Rate (BPS)	Average Data Rate per Scan (BPS)
PICOM Map	1 1 1	1 AMU 4 AMU 14 and 16 AMU	1.0 hr.	1 to 20 AMU	N/A	30	2 sec	15	120	120
GROW Profile	2	20 cm (1.5 GHz)	12 hrs	1 to 4 meters	$2.55^\circ \times 15^\circ$	7	2 sec	7	56	56
VPOC Profile	1 1	0.25μ 0.28μ	2 hrs.		$0.17^\circ \times 3^\circ$	18	20 sec	1.8	14.4	14.4
PROBE Point Value	2		1.0 hr		N/A	13	1 sec.	26	208	208
DATA RELAY Steering Angle and Experiment Data	1 2	2.253 GHz RF Antenna pointing	12 hrs	$0-300^\circ$	N/A	N/A	N/A	N/A	16 steering 6.4×10^5 Exp Data	N/A

SUMMARY OF THE EXPERIMENT CHARATERISTICS

TABLE 2.1-1 (continued)

Table 2.1-2

EXPERIMENT PROCESSING

	CONTROLS: Experiment Management						CONTROLS: Scan			Calibration			Enhancement			
	power	mode	scan control	deployment	onboard chk	pointing	mechanical	satellite	electronic	inflight	lab. curves	comparison	filtering	log e expand	normalization	image ID
RADIOMETERS																
(1) ESMR	x	p	x		x			x	x	x	x		p	p	x	x
(2) HRIR	x	p	x		x		x	x		x	x		p	p	x	x
(3) HRMR	x	p	x		x		x	x		x	p		p	p	x	x
(4) ITPR	x	p	x		x		x	x		x	x		p	p	x	x
(5) SCRWV2	x	x			x			x		x	x	x	p	p	x	x
SPECTROMETERS																
(6) MICSPEC	x	x		p	x			x		x	x		p	p	x	x
(7) PICOM	x	x			x			x		x	x		p	p	x	x
SCATTEROMETER																
(8) GROW	x	p		x	x			x	x	x	x		p	p	x	x
PHOTOMETER																
(9) VPOC	x	p	x		x		x	x		x	x		p	p	x	x
ELECTROSTATIC																
(10)PROBE	x	p	x	p	x			x								x
DATA RELAY																
(11)DAR	x	p		p	x											

	Rectification						Super position				Misc.		Data Compress				Data Hand.	
	attitude	incident ang.	skew	altitude	earth curve.	scaling	ortho-project	contouring	gridding	mosaicking	onboard chk	noise removal	amplitude	adaptive	predictor	redundancy	T/M format	T/M schedule
RADIOMETERS																		
(1) ESMR	x	x	p	x	p	p	p	p	x	p	x	p				p	x	x
(2) HRIR	x	x	p	x	p	p	p	p	x	p	x	p				p	x	x
(3) HRMR	x	x	p	x	p	p	p	p	x	p	x	p				p	x	x
(4) ITPR	x	x	p	p	p	p	p	p	x	p	x	p				p	x	x
(5) SCRWV2	x	x	p	x	p	p	p	p	x	p	x	p				p	x	x
SPECTROMETERS																		
(6) MICSPEC	x	x	p	x	p	p	p	p	x	p	x	p				p	x	x
(7) PICOM	x	x	p	x	p	p	p	p	x	p	x	p				p	x	x
SCATTEROMETER																		
(8) GROW	x	x	p	x	p	p	p	p	x	p	x	p				p	x	x
PHOTOMETER																		
(9) VPOC	x	x	p	p	p	p	p	p	x	p	x	p				p	x	x
ELECTROSTATIC																		
(10)PROBE											x	p	p	x	p		x	x
DATA RELAY																		
(11)DAR	x										x						x	x

p=possible x = included in requirements

ESMR — Electrically Scanned Microwave Radiometer

Inputs:

1. Power ON/OFF
2. Deployment of antenna after orbit is achieved
3. Beam scanning (78 discrete positions for $\pm 50^{\circ}$ field of view)
4. Switching of redundant circuits

Outputs:

1. Data rate: (peak) 360 bit/sec.
2. Serial readout
3. Calibration data: 1 - 10 bit word every 2 minutes
4. Housekeeping data: 1— 10 bit word every 2 minutes

Stabilization and Control:

1. Local vertical orientation
2. $\pm 2^{\circ}$ pointing accuracy

Processing:

1. Concurrent operation with another radiometer
2. Angular Resolution: 1.6 degrees
3. Time constant: 2 seconds
4. Calibration: two sources (50°k and 330°k)
5. Dynamic range: 50°k to 330°k, accurate to 2°k